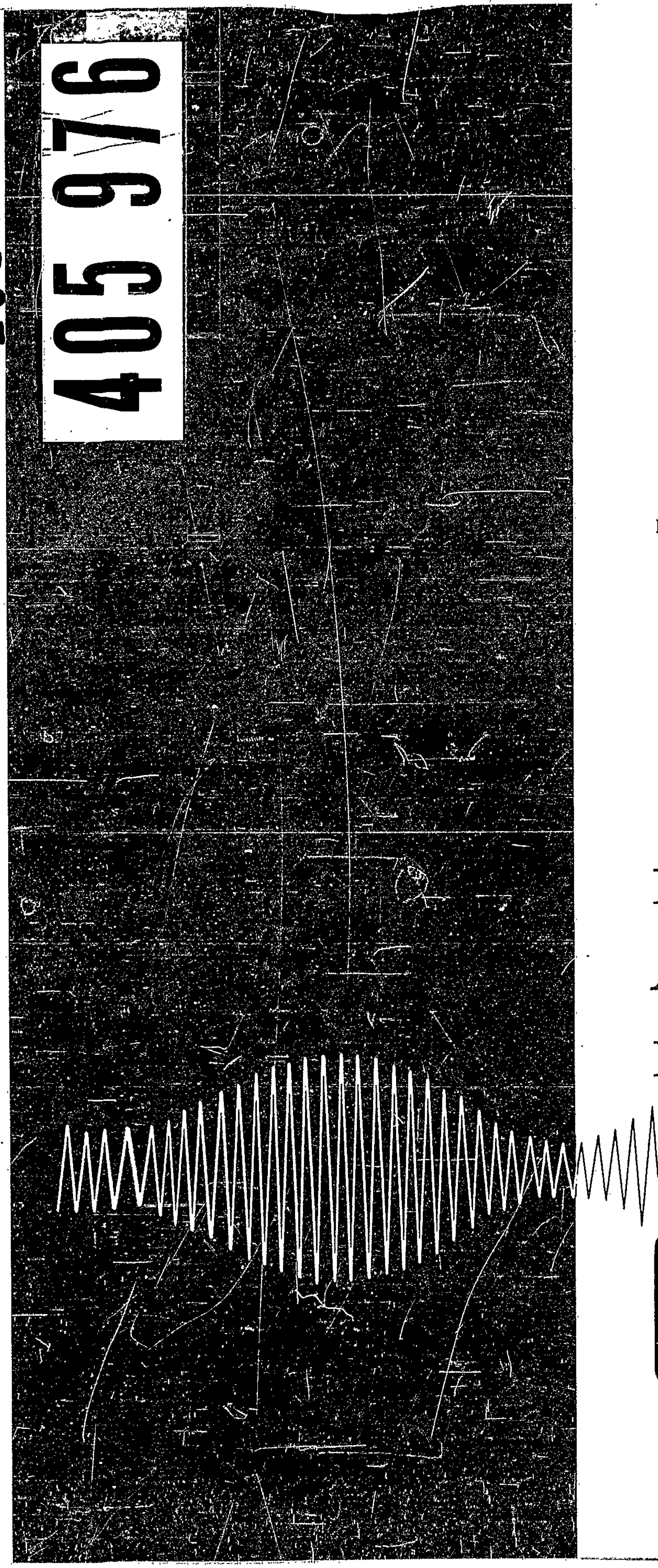

FOURTH QUARTERLY PROGRESS REPORT

1 January 1963 - 31 March 1963

SOLID-STATE

S AND X BAND LIMITERS

Contract NObsr - 87307

Project Serial No. SR0080301, ST9386

Placed by:

Navy Department Bureau of Ships

MICROWAVE ASSOCIATES, INC.
BURLINGTON, MASSACHUSETTS

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Fourth Quarterly Progress Report

SOLID-STATE

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Navy Department Bureau of Ships

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Approved by

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MICROWAVE ASSOCIATES, INC.

Burlington, Massachusetts

May 10, 1963

TABLE OF CONTENTS

ABSTRACT

During the fifth quarterly period of this contract, work was completed on the demonstration of power handling capability phase for both S and X-band limiter designs. Both utilize a first stage high power PIN limiter arrangement and employ power sharing in order to achieve desired peak power handling capability.

Experimental high power results are presented for both X and S-band operation along with preliminary life test data. Also, performance of a novel DC return required in the S-band limiter is also described.

PART I

PURPOSE

The purpose of work conducted under this program is to investigate methods leading to the design of solid-state microwave limiters employing PN junctions at S and X-band. Tentative design goal specifications are as follows:

	S Band	X Band
Peak Power, min.	10	1.0 KW
Avg. Power, min.	10	1.0 W
Insertion Loss, max.	1.0	1.0 DB
Isolation, min.	40	30 DB
Bandwidth, min.	10	7.5 %

In addition, techniques capable of extending operation to even higher power levels will also be reviewed.

GENERAL FACTUAL DATA

A. INTRODUCTION

In this section a brief review is presented on both the varactor and PIN limiter concepts. Advantages and disadvantages of each type are covered along with a tabulated comparison of the two types pointing out their relative advantages and disadvantages.

1. The Varactor Limiter

In Figure (1), general varactor characteristics are illustrated with regard to constructional features equivalent circuit, impedance characteristics as a function of applied bias and its reactance voltage relationship. Inspection of these characteristics show the varactor to be a variable reactance type diode of a generally lossless nature. By placing it in a suitable microwave structure, as described in previous quarterly reports, it can be made to perform as a microwave limiter; that is, exhibiting an insertion loss characteristic which varies as a function of applied incident power level. This is brought about by interaction with the applied RF signal voltage causing the varactor to radically change impedance states. As applied RF voltage increases, the time average varactor junction capacitance also increases. In turn, the limiter structure (diode and circuit) changes its appearance from a low loss transmission line to a short circuited transmission line causing the bulk of applied power to be reflected with a small portion being transmitted.

To date, at S-band, operation of varactor limiters has been secured up to 1.0 KW peak on a repeatable basis. However, increasing this rating to values of 5 KW or greater has proven difficult. This difficulty arises

as a result of varactor diode junction size requirements. So that practical low insertion loss characteristics under low power can also be secured, a restriction is placed on varactor capacitance and hence junction size. These are approximately 0.5 to 1.0 pf and 1.0 to 2.5 mills diameter respectively for S-band operation. Results to date have shown that these junction sizes are too small for 5 KW power operation. This comes about by virtue of the varactors inability to withstand the power dissipated. This is typically 10% of the incident level since some dissipation loss is incurred due to a finite series resistance being present. At the lower frequencies, this problem eases up for larger capacitance units can be utilized with correspondingly higher power capabilities and yet retain low insertion loss characteristics.

At X-band the same problem is encountered but more severe as one might expect. Here, maximum usable junction capacitance is approximately 0.2 pf and power handling capability is limited to only several hundred watts peak.

2. <u>The Switched PIN Diode Limiter</u>

Also shown in Figure (1) are characteristics of the PIN diode. This form of diode has been described in previous quarterly reports. As can be seen, on a constructional basis, it differs from the varactor by the presence of a relatively thick I region (intrinsic semiconductor layer). Because of this, the PIN diode exhibits the properties of a voltage sensitive variable resistance. Also, it allows the PIN diode to have a much lower capacitance per unit area characteristic. This enables a larger power dissipation characteristic to be achieved for a given junction capacitance

value and hence higher power operation capabilities.

However, the presence of the I region also results in the disadvantage of slowness of operation. Carriers from the P+ and N+ region must move a relatively large distance to ionize the I region which is necessary to secure a short circuited condition. This is made quite evident in operation at S-band by the PIN diode's inability to directly interact with applied RF voltage. If the voltage is made sufficiently high, a "brute force" form of limiting is achieved but power dissipation will become excessive despite the relatively large junction area involved.

To overcome this, a sample of the applied RF voltage is coupled into a high burnout crystal detector diode and rectified. This signal is then fed into the PIN diode causing it to change impedance states and thus exhibit the essential properties of a limiter. Despite this, slowness of operation is still evident by the presence of a leading edge RF leakage spike similar to that associated with a conventional TR tube. However, dissipation in the PIN diode is reduced to a safe level.

To date, this form of operation has been achieved up to 5 KW at S-band with satisfactory low level insertion loss characteristics. At X-band 1 KW has been secured to date.

3. Comparison of PIN and Varactor Limiters

From previous discussion, one can easily foresee that a desirable form of limiter at both S and X-bands could employ a PIN first stage and varactor second stage configuration. This would take advantage of the PIN diode's ability to handle high power. The varactor would be employed to cope with the RF leakage spike since this form of diode is very fast in operation. Its use is made possible by the greater portion of applied power

being reflected by the previous PIN diode stage.

In order to gain a clearer insight on the form of design, characteristics of PIN and varactor limiter at S and X-bands are tabulated and presented in TABLE (I). All results quoted have been achieved in practice. As for the life test data presented, these results are based on preliminary tests and do not indicate failure points in time. Additional tests are planned in the near future. With respect to PIN diode limiter spike leakage values, both S and X-band results are sufficiently low to enable a following varactor stage to be safely employed.

TABLE I

VARACTOR AND SWITCHED PIN LIMITER

CHARACTERISTICS AT S AND X-BAND (SINGLE DIODE)

CHARACTERISTIC	S-BAND PERFORMANCE		X-BAND PERFORMANCE	
	VARACTOR	PIN DIODE	VARACTOR	PIN DIODE
INSERTION LOSS	0.3 DB	0.35 DB	0.35 DB	0.6 DB
PEAK INCIDENT POWER	1.0 KW	5 KW	250 W	1 KW
SPIKE LEAKAGE (MAX)	-----	600-800 ergs	-----	50 - 100 ergs
FLAT LEAKAGE (MAX)	30 DB	28 DB	25 DB	28 DB
LIFE TEST INFORMATION TO DATE	None available as of date	134 hours	300 hours	500 hours

DETAILED FACTUAL DATA

A. S-BAND EXPERIMENTAL RESULTS

In Figure (2), an illustration of a switched PIN diode limiter is shown with associated performance characteristics. Total leakage power and isolation are plotted as a function of applied incident power. As can be seen, all effective isolation has taken place shortly after a peak power level of 2.5 KW has been reached. When a level of 5.0 KW is subjected to the PIN diode limiter, all leakage power can be considered as spike with a resultant value of approximately 500 ergs.

This particular unit had a mid band (3000 MC) insertion loss value of 0.2 DB which is about the best value achieved to date. Typically, 0.35 DB is more reasonable to expect.

With respect to the PIN limiter configuration in Figure (2), the biasing crystal is shown preceeding the PIN diode limiter circuit. Bias current is applied through the coaxial RF choke which enablesan RF short and DC open circuit to be achieved. In order to complete the current path, an external DC return was used. Obviously, it would be desirable to incorporate this in the limiter body itself and some effort has been recently devoted to this aspect. In Figure (3), performance of a printed circuit DC return that can be placed in a standard type N connector is shown. It consists of a thin spiral that makes contact with both outer and inner conductor of the coaxial line. As can be seen, results are quite good and it will be used in the S-band limiter final design to make it a completely self contained unit.

B. X-BAND EXPERIMENTAL RESULTS

In Figure (4) an X-band PIN diode limiter configuration and associated performance is illustrated. The biasing crystal is decoupled from the applied RF power by placing it in a small recess in the side wall of the waveguide. As can be seen, bias is applied through an RF choke in a similar fashion as previously described in the S-band unit. Mid band (9150 MC) insertion loss for this unit was 0.6 DB and represents a typical value that can be expected.

Inspection of total leakage output as a function of applied power shows isolation continues to increase up to 1.0 KW peak power. In all probability, this particular unit could have been satisfactorily run at higher power levels. In fact, a similar structure has been successfully operated up to 2.5 KW peak power but insertion loss was 1.5 DB. This high loss was due to a relatively large junction capacitance which no doubt also enabled it to achieve the large peak power handling capability. In conjunction with this, a short life test was conducted at the 2.5 KW power level and no deterioration in performance was noted after 137 hours of operation.

CONCLUSIONS

Single limiter capabilities of 5.0 KW and 1.0 KW at S and X-bands respectively have been established with associated reasonably low values of insertion loss. By combining two of these units with 3 DB hybrids, this capability can be doubled.

In addition, X-band tests have been successfully run up to 2.5 KW peak which indicates a further increase in power handling capability can be achieved. However, some diode development remains to be done since insertion loss for this case was 1.5 DB. This value is too high with respect to the design goal of 1.0 DB.

PART II

PROGRAM FOR NEXT INTERVAL

During the final period of this contract, designs will be finalized for both S and X-band limiter configurations. Units will be then built and performance characteristics established. If time permits, new diode types will be tested as they become available in order to secure highest possible peak power performance.

LIST OF ILLUSTRATIONS

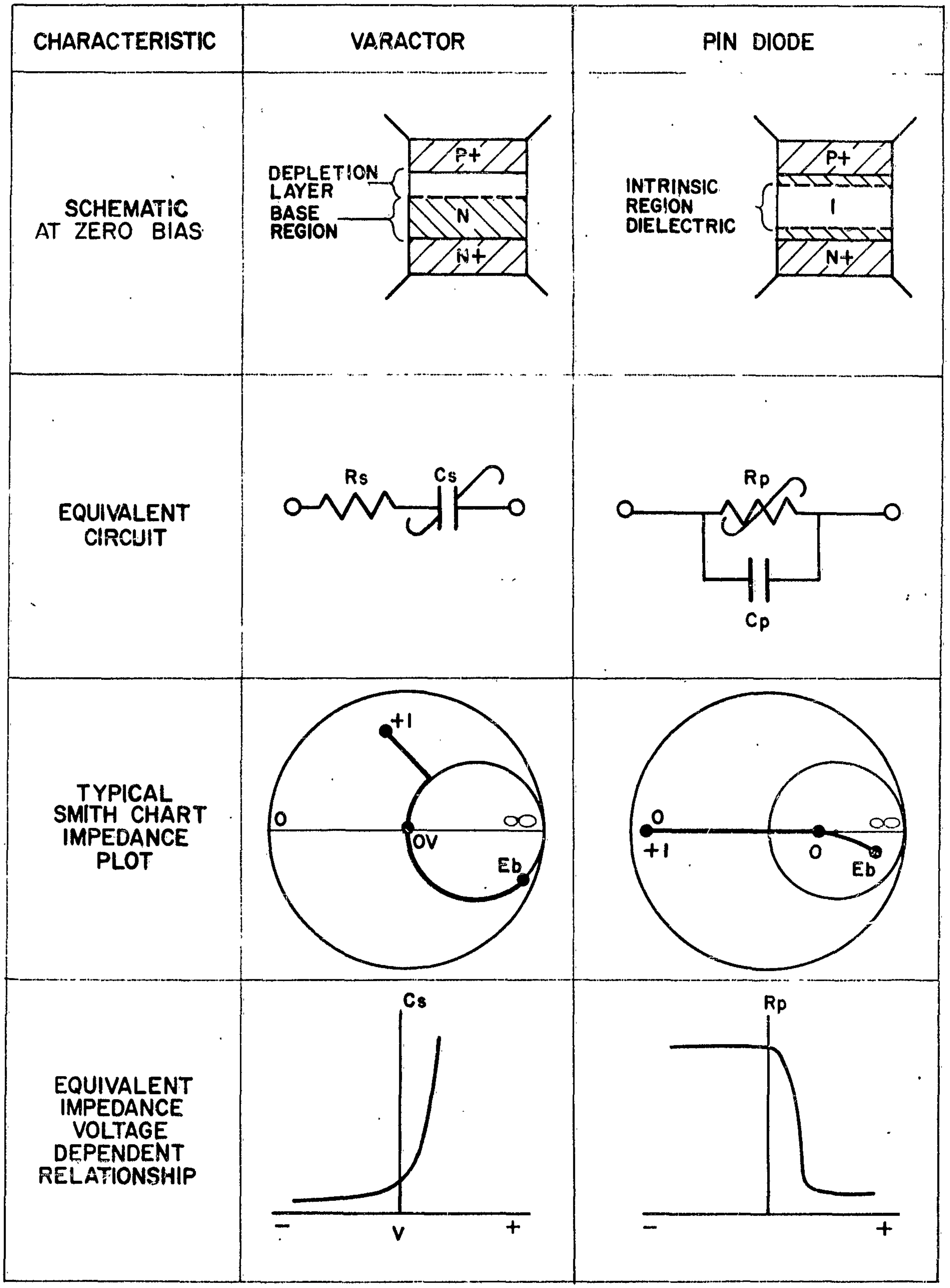


FIGURE 1
GENERAL CHARACTERISTICS OF VARACTORS AND PIN DIODES

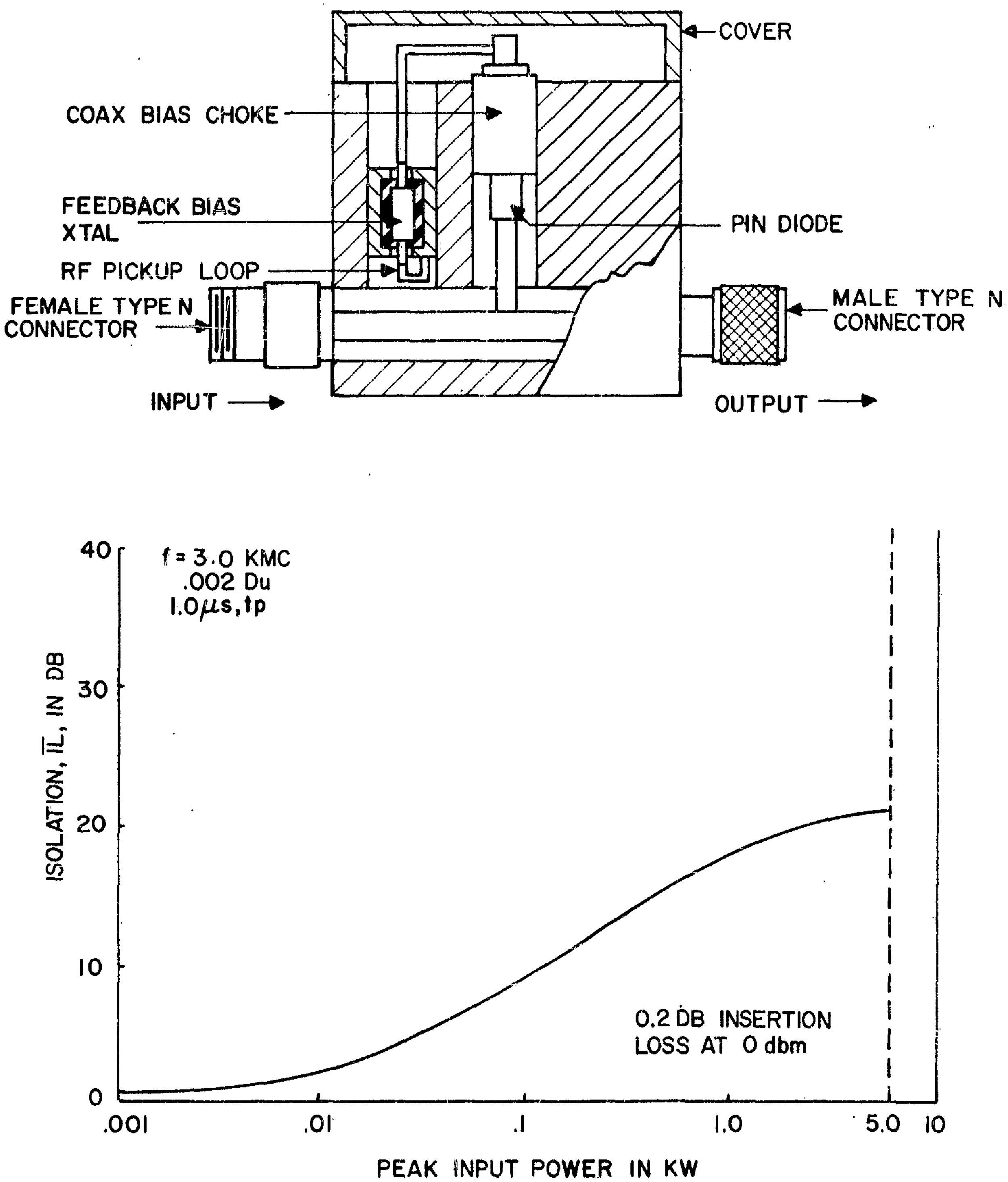
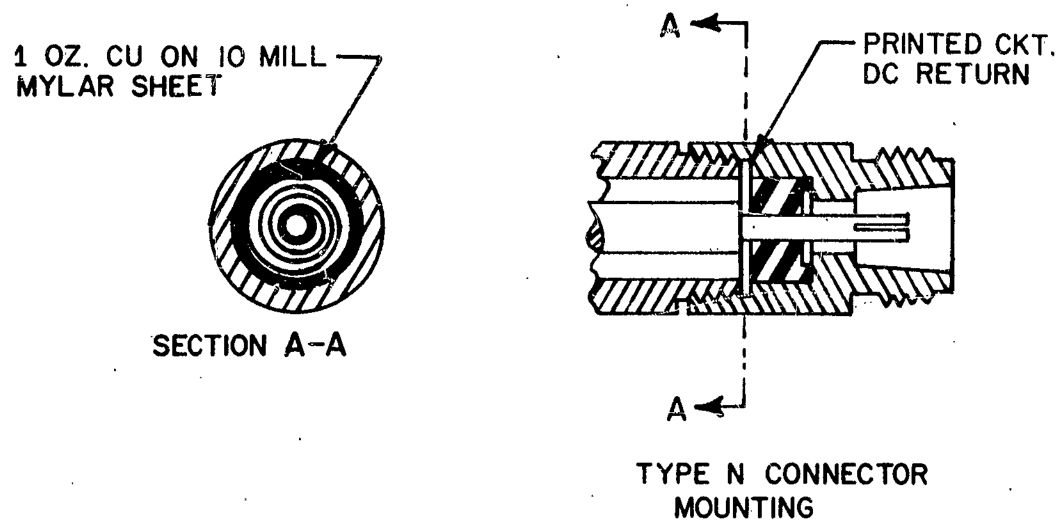


FIGURE 2

S-BAND 5 KW PIN LIMITER CONFIGURATION
AND ASSOCIATED PERFORMANCE CHARACTERISTICS



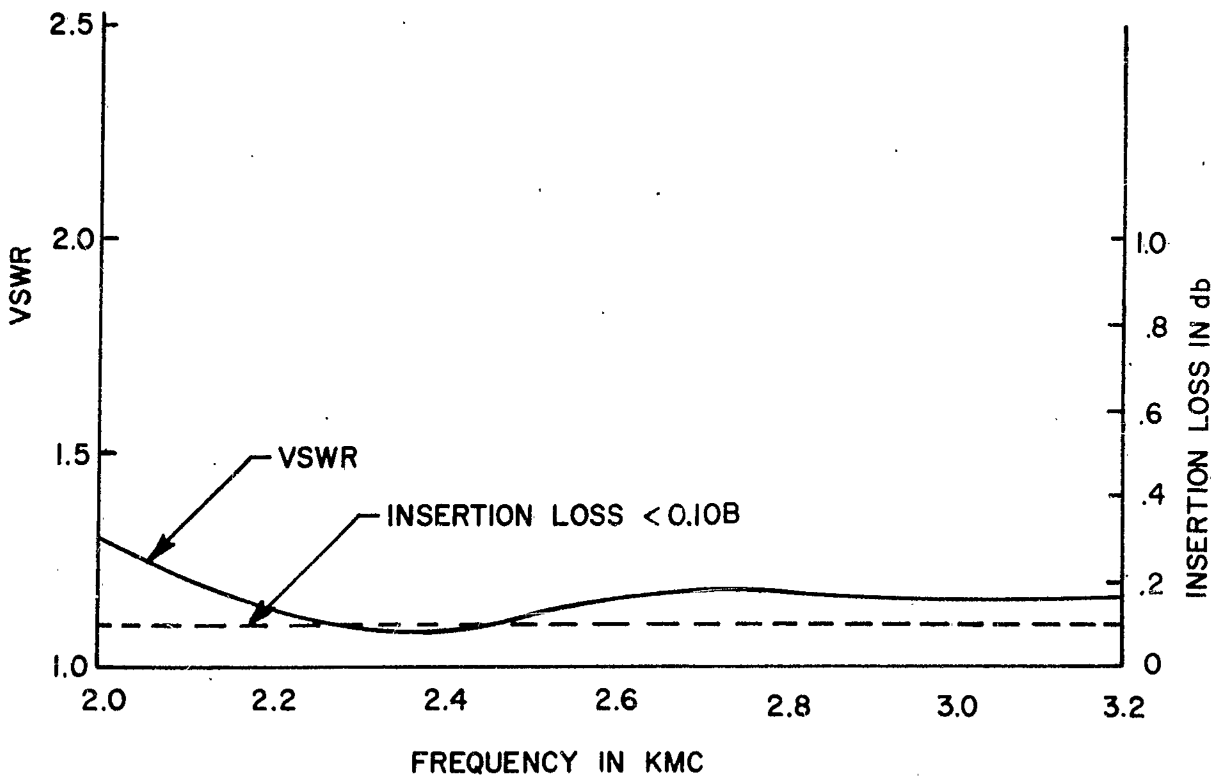


FIGURE 3

S-BAND PRINTED CIRCUIT DC RETURN

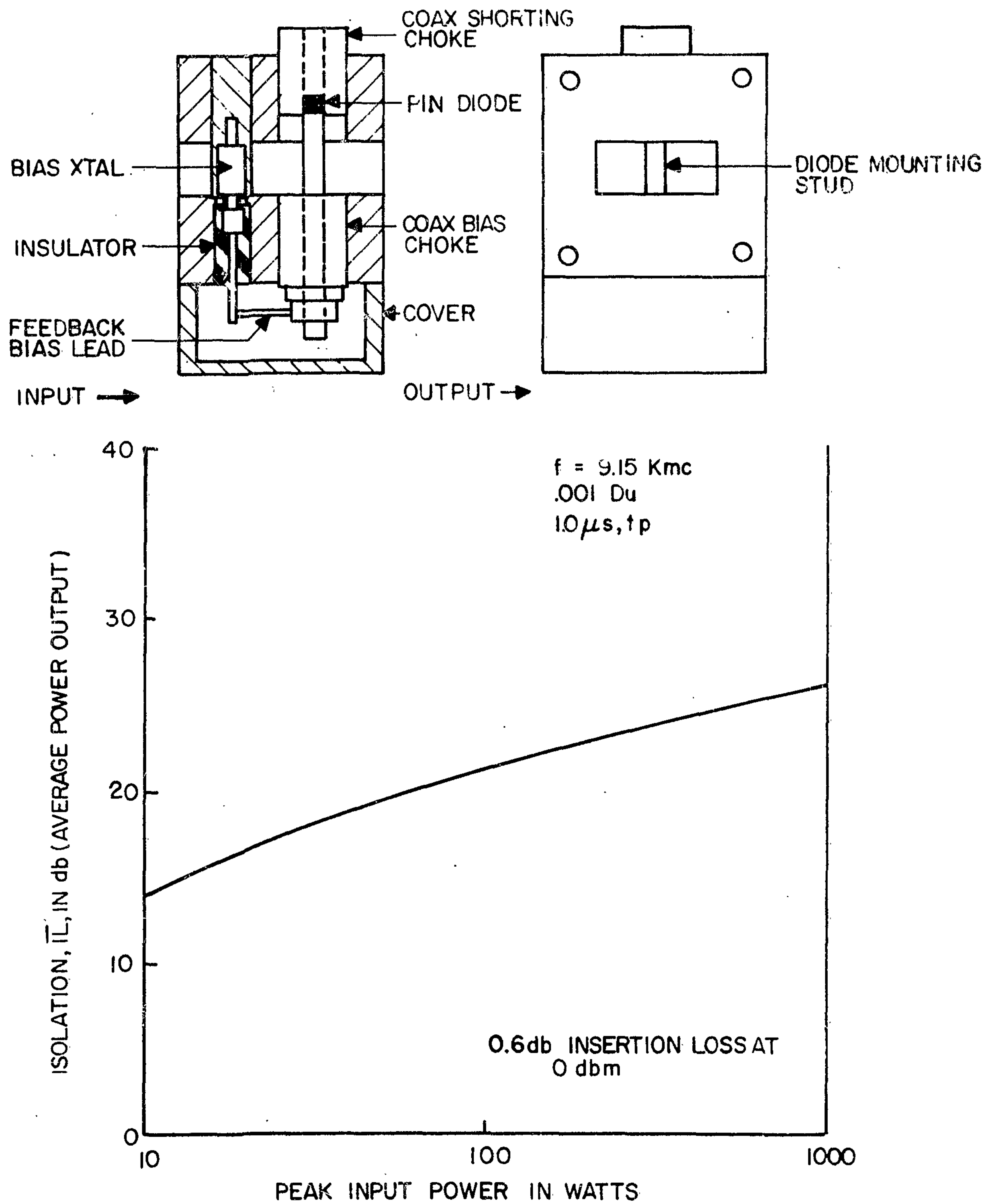


FIGURE 4

BAND I KW SWITCHED PIN LIMITER CONFIGURATION AND ASSOCIATED PERFORMANCE CHARACTERISTICS